CLAIMS

1. A method of testing in pure bending, optionally in alternating bending, the method comprising the following succession of steps:

a) making or selecting a testpiece (1) having two mutually opposite end grip zones (3, 4) and a bending zone (2) interconnecting the two grip zones (3, 4), said testpiece (1) presenting, in a rest state, a first mean plane (5) crossing the bending zone (2) and each of the grip zones (3, 4) and constituting a first plane of symmetry at least for the bending zone (2), and a mean surface (6) for the bending zone (2) and each of the grip zones (3, 4), which mean surface (6) is perpendicular to the first mean plane (5);

b) while leaving the testpiece (1) in the rest state, rigidly securing its two grip zones (3, 4) so as to define for each of them a respective pivot axis (26, 89) perpendicular to the first mean plane (5) and occupying a determined position firstly relative to the respective grip zone (3, 4) and secondly relative to the mean surface (6); and

c) imparting controlled opposing turning movements to the two grip zones (3, 4) of the testpiece (1), optionally in alternation, about the respective pivot axes (26, 89) and away from the rest state, while leaving the pivot axes (26, 89) free to move towards each other or apart from each other, so as to impart optionally alternating bending to the bending zone (2) and so as to study the behavior of the bending zone in pure bending;

the method being characterized in that it is implemented simultaneously on two mutually identical testpieces (1) by implementing:

· step b) in such a manner that the first mean planes (5) of the two testpieces are mutually parallel and the mean surfaces (6) of the two testpieces are mutually symmetrical about a point (22) when the two testpieces are in the rest state, and in such a manner

that the pivot axes (26, 89) of the two testpieces are common and mutually symmetrical about said point (22); and

· step c) by applying optionally alternating opposing torques in controlled manner about each pivot axis (26, 89) to the respective corresponding grip zones (3, 4) so as to impose optionally alternating opposing bending movements to the bending zones (2) of the two testpieces, while allowing the pivot axes (26, 89) to move freely relative to each other.

2. A method according to claim 1, the testpiece (1) presenting as its mean surface (6) in its rest state, a second mean plane (6) constituting a second plane of symmetry at least for the bending zone (2), the method being characterized in that step b) is implemented in such a manner that the second mean planes (6) of the two testpieces coincide when the two testpieces are in the rest state and the pivot axes (26, 89) are placed in the second mean planes (6), which thus coincide.

3. A method according to claim 1 or claim 2, the testpiece (1) presenting in its rest state a third mean plane (7) which is perpendicular to the first mean plane (5) which is crossed by the bending zone (2) with the grip zones (3, 4) being disposed on respective opposite sides thereof, and constitutes a third plane of symmetry, at least for the bending zone (2), the method being characterized in that step b) is implemented in such a manner that the third mean planes (7) of the two testpieces coincide and the pivot axes (26, 89) are mutually symmetrical about the third mean planes (7) which thus coincide.

4. A method according to any one of claims 1 to 3, characterized in that, during step c), the behavior of the bending zone (2) of the testpieces (1) in pure

bending is studied by measuring the resistance opposed to said turning by at least one of the grip zones (3, 4), in particular to deduce therefrom changes in the resistance to bending of the bending zone (2).

5. A method according to any one of claims 1 to 4, characterized in that step b) is implemented by connecting each of the grip zones (3, 4) to the corresponding respective pivot axis (26, 89) by an arm (30, 31, 98, 99), the arms (30, 31, 98, 99) corresponding to the grip zones of the two testpieces being mutually symmetrical about said point (22), and by connecting the two arms (30, 31, 98, 99) corresponding to a given pivot axis (26, 89) by means of a respective controlled motor suitable for imparting optionally alternating opposing turning movements to the two arms (30, 31, 98, 99) about the corresponding pivot axis (26, 89), the controlled motors (105, 106) corresponding to the two pivot axes (26, 89) being mutually identical and being allowed to move freely relative to each other.

6. A method according to claim 5 as dependent on claim 4, characterized it that step b) is implemented by causing each arm (30, 31, 98, 99) to be elastically flexible in the first mean plane (5) of the corresponding testpiece (1) with stiffness that is greater than the stiffness of the bending zone (2) of the testpiece, while otherwise being rigid, and in that during step c) the resistance opposed to turning is measured by measuring the bending stresses to which at least one of the arms (30, 31, 98, 99) is subjected in the first mean plane (5) of the corresponding testpiece (1).

7. A method according to claim 5 or claim 6, characterized in that the arms (30, 31) and the controlled motors (105) are arranged in such a manner that during step b) the pivot axes (26) are mutually

parallel and disposed respectively on either side of said point (22).

8. A method according to claim 7, as dependent on claim 3, the third mean plane (7) of the testpiece (1) constituting a mutual plane of symmetry for its grip zones (3, 4), the method being characterized in that the arms (30, 31) corresponding to the grip zones of the two testpieces are mutually identical.

9. A method according to claim 5 or claim 6, characterized in that the arms (98, 99) and the controlled motors (106) are arranged in such a manner that during step b), the pivot axes (89) coincide and pass through said point (22).

10. A method according to any one of claims 1 to 9, characterized in that during step a) each testpiece (1) is made or selected in such a manner as to be in the form of a plate of thickness (e) extending perpendicularly to the mean surface (6).

11. A method according to claim 10, characterized in that during step a) each testpiece (1) is made or selected in such a manner that said thickness (e) is also constant, at least in the bending zone (2).

12. A method according to claim 10 or claim 11, characterized in that during step a), each testpiece (1) is made or selected in such a manner that it presents a dimension (L_1) perpendicular to the first mean plane (5) that is constant, at least in the bending zone (2).

13. A method according to any one of claims 10 to 12, characterized in that during step a) each testpiece (1) is made or selected in such a manner as to present a respective transition (107) perpendicularly to the first

mean plane (5) between the bending zone (2) and each of the grip zones (3, 4).

14. Test apparatus for testing a testpiece (1) in pure bending, optionally in alternating bending, the testpiece (1) comprising two mutually opposite end grip zones (3, 4) and a bending zone (2) interconnecting the two grip zones (3, 4), said testpiece (1) presenting, in a rest state, a first mean plane (5) crossing the bending zone (2) and each of the grip zones (3, 4), and constituting a first plane of symmetry at least for the bending zone (2), and a mean surface (6) for the bending zone and for each of the grip zones (3, 4), which mean surface (6) is perpendicular to the first mean plane (5), said apparatus (18, 19, 20) comprising:

· a pair of clamps (32, 33, 100, 103) each defining a slot (46, 51) for securely gripping a respective grip zone (3, 4) of the testpiece (1), the slots (46, 51) presenting, in a relative rest position corresponding to the testpiece (1) being in the rest state, a first mean plane (34) which crosses each of the slots (46, 51), and a mean surface (35) for each of the slots (46, 51), with each slot (46, 51) presenting on either side of the mean surface (35) a respective clamping face (52, 53) for clamping the corresponding grip zone (3, 4) of the test-piece (1) and with the mean surface extending perpendicularly to the first mean plane (34) of the slots (46, 51);

· means (27, 28, 30, 31, 93, 94, 98, 99) for defining a respective pivot axis (26, 89) for each clamp in such a manner that in the relative rest position of the clamps (32, 33, 100, 103), the pivot axes (26, 89) are perpendicular to the first mean planes (34) of the slots (46, 51), and occupy determined positions relative to the corresponding clamps (32, 33, 100, 103) and are free to move towards each other or apart from each other;

· controlled means (105, 106) for imparting opposing, optionally alternating turning movements to the clamps (32, 33, 100, 103) about the corresponding pivot axes (26, 89) away from the relative rest position of the clamps (32, 33, 100, 103), while leaving the pivot axes (26, 89) free to move towards each other or apart from each other; and

· means (82, 83, 84, 86) for measuring the behavior of the bending zone (2) of the testpiece (1) in pure bending;

the apparatus being characterized in that it in order to implement the method according to any one of claims 1 to 13:

· it includes two mutually identical sets of said pair of clamps (32, 33, 100, 103), having the first mean planes (34) of their slots (46, 51) mutually parallel and having the mean surfaces (35) of the slots (46, 51) mutually symmetrical about a point (22) when the two sets are occupying their rest positions in which each of them is suitable for receiving a respective testpiece (1) in the rest position with the two testpieces being in a relative position such that they are mutually symmetrical about said point (22);

· the means (27, 28, 30, 31, 93, 94, 98, 99) for defining the pivot axes (26, 89) of the clamps (32, 33, 100, 103) of the two sets are arranged in such a manner that the pivot axes (26, 89) are common to both sets, being mutually symmetrical about said point (22) when the two sets are occupying their rest positions, and being free to move relative to each other; and

· the controlled means (105, 106) for imposing opposing and optionally alternating turning movements on the clamps (32, 33, 100, 103) of the two sets comprise controlled motor means (105, 106) for applying opposing, optionally alternating torques about each pivot axis to the corresponding clamps (32, 33, 100, 103).

15. Apparatus according to claim 14, each testpiece (1) presenting as its mean surface (6) in its rest state, a second mean plane (6) constituting a second mean plane of symmetry at least for the bending zone (2), the slots (46, 51) of said pair of clamps (32, 33, 100, 103) possessing as mean surface (35) respective second mean planes (35) between the clamping faces (52, 53) of each clamp (32, 33, 100, 103) when in the rest position,

the apparatus being characterized in that the second mean planes of the two sets of said pair are mutually symmetrical about said point (22) when the two sets are in the rest position.

16. Apparatus according to claim 15, in which each test-piece (1) in its rest state presents a third mean plane (7) that is perpendicular to the first mean plane (5), that is crossed by the bending zone (2) when the grip zones (3, 4) are disposed respectively on either side thereof, and that constitutes a third plane of symmetry at least for the bending zone (2), and the slots (46, 51) of said pair of clamps (32, 33, 100, 103) present, in the rest position, a third mean plane (108) on either side of which they are disposed and which is perpendicular to their first mean plane (34),

the apparatus being characterized in that the third mean planes of the two sets of said pair are mutually symmetrical about said point (22) when the two sets are in the rest position.

17. Apparatus according to any one of claims 14 to 16, characterized in that the means (82, 83, 84, 86) for measuring the behavior of the bending zone (2) of the testpieces (1) in pure bending comprise:

· means (82, 83, 84) for measuring the resistance opposed to said alternating turning movements by at least one of the clamps (32, 33, 100, 103); and, where appropriate

· means (86) for deducing therefrom how the resistance of the testpiece (1) to bending between the clamps (32, 33, 100, 103) changes.

18. Apparatus according to any one of claims 14 to 17, characterized in that:

· the means (27, 28, 30, 31, 98, 99) for defining the pivot axes (26, 89) of the two sets comprise:

· on each of the pivot axes (26, 89), two respective shafts (27, 28, 93, 94) on the same axis and mounted to turn relative to each other about the corresponding pivot axis (26, 89); and

· four arms (30, 31, 98, 99) that are mutually symmetrical about said point (22), each connecting a respective one of the shafts (27, 28, 93, 94) to a respective one of the clamps (32, 33, 100, 103) corresponding to the same pivot axis (26, 89); and

· the controlled motor means (105, 106) for applying opposing, optionally alternating torques about each pivot axis (26, 89) to the corresponding clamp (32, 33, 100, 103) comprise two mutually identical controlled motors (105, 106) arranged in such a manner as to be capable of moving freely relative to each other, each of the motors (105, 106) being associated with a respective one of the pivot axes (26, 89) and being suitable for imparting opposing, optionally alternating, turning movements to the two respective corresponding shafts (27, 28, 93, 94).

19. Apparatus according to claim 18, characterized in that the motors (105, 106) are electric stepper motors.

20. Apparatus according to claim 18 or claim 19 as dependent on claim 17, characterized in that each arm (30, 31, 98, 99) is elastically flexible in the first mean plane (34) of the slot (46, 51) of the corresponding clamp (32, 33, 100, 103) with stiffness greater than the stiffness of the bending zone (2) of the corresponding

testpiece, and is otherwise rigid, and in that the measurement means (82, 83, 84) comprise means (82, 83) for measuring the bending stresses to which at least one of the arms (30, 31, 98, 99) is subjected in the first mean plane (34) of the slot (46, 51) of the corresponding clamp (32, 33, 100, 103).

21. Apparatus according to claim 20, characterized in that the arms (30, 31, 98, 99) present in mutually symmetrical positions about said point (22) at least one respective zone (75) that is weakened in bending in the first mean plane (34) of the slot (46, 51) of the corresponding clamp (32, 33, 100, 103), and

in that the means (82, 83) for measuring bending stresses are located in said zone (75) of at least one of the arms (30, 31, 98, 99).

22. Apparatus according to any one of claims 18 to 21, characterized in that the arms (30, 31), the shafts (27, 28), and the motors (105) are arranged in such a manner that in the rest position the pivot axes (26) are mutually parallel and disposed respectively on either side of said point (22).

23. Apparatus according to claim 22 as dependent on claim 16, the third mean plane (6) of each testpiece (1) constituting a plane of mutual symmetry for the grip zones (2, 3),

the apparatus being characterized in that the arms (30, 31) are mutually identical.

24. Apparatus according to any one of claims 18 to 21, characterized in that the arms (98, 99), the shafts (93, 94), and the motors (106) are arranged in such a manner that, in the rest position, the pivot axes (89) coincide and pass through said point (22).

25. Apparatus according to any one of claims 14 to 24, characterized in that the clamps (32, 33, 102, 103) are chamfered so as to taper towards each other when the clamps (32, 33, 102, 103) are in the rest position.

26. A testing machine for performing testing in pure bending, optionally in alternating bending, for implementing the method according to any one of claims 1 to 13, the machine being characterized in that it comprises:

· two mutually identical motor assemblies (21, 90) that are mechanically mutually independent, each comprising:

· two clamps (32, 33, 102, 103) each of which is suitable for securely receiving a respective grip zone (3, 4) of a corresponding testpiece (1);

· means (27, 28, 30, 31, 93, 94, 98, 99) for defining a relative pivot axis (26, 89) for the two clamps (32, 33, 102, 103) and occupying a determined position relative to each of the two clamps (32, 33, 102, 103) while in a relative rest position; and

· controlled motor means (105, 106) for imparting relative and optionally alternating turning movements to the clamps (32, 33, 100, 103) about the relative pivot axis (26, 89) away from the relative rest position; and

· common means (86) for controlling the motor means (105, 106) of the two motor assemblies (21, 90) to impart relative, optionally alternating turning movements to the respective clamps (32, 33, 100, 103) about the respective relative pivot axes (26, 89).

27. A machine according to claim 26, characterized in that it comprises:

· means (82, 83, 84) for measuring the resistance to relative turning opposed by at least one of said clamps (32, 33, 100, 103).

28. A machine according to claim 26 or claim 27, characterized in that for each of said motor assemblies (21, 90) respectively:

· the means (27, 28, 30, 31, 93, 94, 98, 99) for defining the relative pivot axes (26, 89) of the two clamps (32, 33, 100, 103) comprise:

· two shafts (27, 28, 93, 94) mounted on the same axis to turn relative to each other about the relative pivot axis (26, 89); and

· two arms (30, 31, 98, 99), each of which secures one of the clamps (32, 33, 100, 103) to a respective one of the shafts (27, 28, 93, 94); and

· the controlled motor means (105, 106) for imparting relative, optionally alternating turning movement to the clamps (32, 33, 100, 103) about the relative pivot axes (26, 89), comprise a controlled motor (105, 106) that is mechanically independent of the control motor (105, 106) of the other motor assembly (21, 90) and that is suitable for imparting relative, optionally alternating, turning movements to the two shafts (27, 28, 93, 94).

29. A machine according to claim 28, characterized in that each controlled motor (105, 106) is an electric stepper motor.

30. A machine according to claim 28 or claim 29, as dependent on claim 27, characterized in that each arm (30, 31, 98, 99) is elastically flexible in a mean plane (34) perpendicular to the pivot axis (28, 89) and is otherwise rigid, and in that the measurement means (82, 83, 84) comprise means (82, 83) for measuring the bending stresses to which at least one of the arms (30, 31, 98, 99) is subjected in said mean plane (34).

31. A machine according to claim 30, characterized in that each arm (30, 31, 98, 99) presents at least one zone (75) that is weak in bending in said mean plane (34), and in that the means (82, 83) for measuring bending stresses are located in said zone (75) of at least one of the arms (30, 31, 98, 99).

32. A machine according to any one of claims 26 to 31, characterized in that the arms (30, 31) are mutually identical.

33. A machine according to any one of claims 26 to 32, characterized in that the clamps (32, 33, 100, 103) are chamfered.